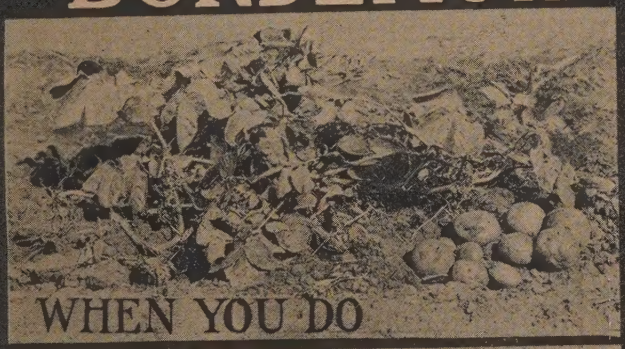
Bulletin 334 July 1921

J. E. Dudley Jr. & H. F. Wilson.

COMBAT POTATO LEAFHOPPER WITH BORDEAUX



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DIGEST

The potato leafhopper is a deadly menace to the potato crop in the Middle West and East. Page 3

The insects are very small but often occur in vast numbers and in feeding rob plants of much of their sap. Page 7

Hopperburn may result in large losses to potato growers. This is a diseased condition of the foliage caused by the leafhopper. Page 7

Early Triumph potatoes are much more severely affected with hopperburn than are Rurals and other Wisconsin potatoes. Page 14

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Combat Potato Leafhopper with Bordeaux

J. E. Dudley, jr.,* and H. F. Wilson

The potato leafhopper is one of the most important enemies of the potato in the United States.

Serious outbreaks have occurred periodically in certain sections of the United States since the early eighties, but not until 1896[1] was the leafhopper known as a dangerous menace to the potato crop in the Middle West and East. It attacks a large number of plants and occurs commonly on the apple, the plant from which it was first described.[2] The leafhopper sucks the juices from the plants so that the foliage turns yellow and the leaves curl and wither. Under ordinary circumstances this is not serious but another injury accompanies the feeding of the leafhopper and causes the rapid death of the plant if nothing checks its spread.

A diseased condition is produced in some manner in the plant which causes the foliage to blacken and die. The cause of this is not well understood, but the indications are that a toxin, or possibly a disease, is transmitted through the feeding punctures of the leafhopper and that the effect spreads rapidly to all parts of the plant.

The disease itself has not been studied, but many observations upon the spread of the injury and the gross effect upon the plant have been made to learn the conditions under which the injury develops.

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[1]Osborn, Herbert. A New Pest of Potatoes. Iowa Expt. Sta. Bul. 33. 1896.

[2]*Empoasca mali.* This species has been called the apple leafhopper in many publications for the past fifty years. In order to distinguish it from the true apple leafhopper *(Empoasca unicolor)* the name of its principal host, the potato, has been used for its proper common name.

Seasonal History is Important

The potato leafhopper (Fig. 1) lives over winter in the adult stage, hidden away in brush heaps, matted weeds, and other protected places. In late May or early June the "hoppers" emerge from their winter quarters, feed for a week or ten days on trees and shrubs, then suddenly migrate to potatoes and beans where mating and egg laying begin. During the first week after emergence in the spring, the females greatly outnumber the males often by ten to one.

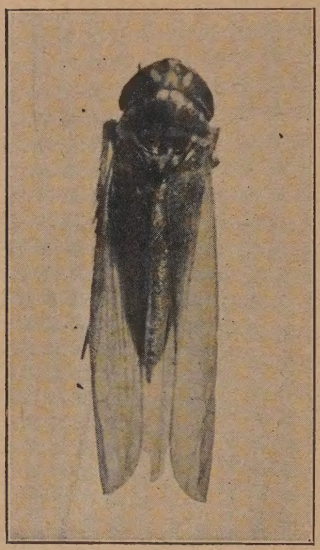

FIG. 1.—ADULT POTATO LEAFHOPPER
Enlarged 20 times.

Eggs — Tiny, transparent, very delicate eggs, about $\frac{1}{30}$ of an inch in length are inserted by the female into the midrib and stem of the potato leaf. (Fig. 1-A and Fig. 2-A). The eggs cannot be seen from the outside and careful dissection of the midrib is necessary to disclose them. During the incubation period the eggs change from transparent white to yellow. Two red spots, the eye of the developing leafhopper, appear. Under artificial conditions eggs hatch in from 9 to 11 days into young leafhoppers called nymphs. Under field conditions the incubation period appears to be somewhat longer.

Nymphs—Newly-hatched nymphs are very small, wingless, and nearly white. They start at once to suck juices from the plant and gradually turn yellow, then greenish in color. They pass through five distinct stages or periods of growth, and shed the skin at the end of each stage. (Fig. 2, B to F). When quite young the nymphs move around but little and are nearly always found on the under side of the leaves. When disturbed, however, they move quickly to the top of the leaf going sidewise like

a crab. During the fourth and fifth stages, (Fig. 2, E and F) they are more active and frequently hop from leaf to leaf. At this time, they are quite green and the partially developed wings are easily seen at the middle of each side of the body. An average of 17 days is required from the hatching of the egg until the adult stage is reached.

Adults—The full grown leafhopper is a small pale-green insect about 1/8 of an inch long, with thin irridescent wings, large white eyes and a more or less distinct H on the thorax. (Fig. 2, G) There are six roundish white blotches at the top of this H and three white, wedge-shaped blotches below it. These marks serve to identify the insect.

FIG. 1-A.—TINY TRANSPARENT EGG OF LEAFHOPPER LAID IN STEM OF BEAN PLANT

Enlarged 6 times.

Two Generations in Wisconsin—Two generations of the insect are produced in one summer. Most of the over-wintered adults have died off by the middle of July while their young develop into adults and form one complete generation appearing about the last of July. A second generation is then developed. The young pass through the same stages as the first generation although in a slightly shorter time, and a new brood of adults begins to appear about September 1. This brood lives over winter. Many careful tests have shown that this second generation does not reproduce until the following summer.

Although the appearance of adults of each summer generation is limited to two distinct periods of about two weeks each,

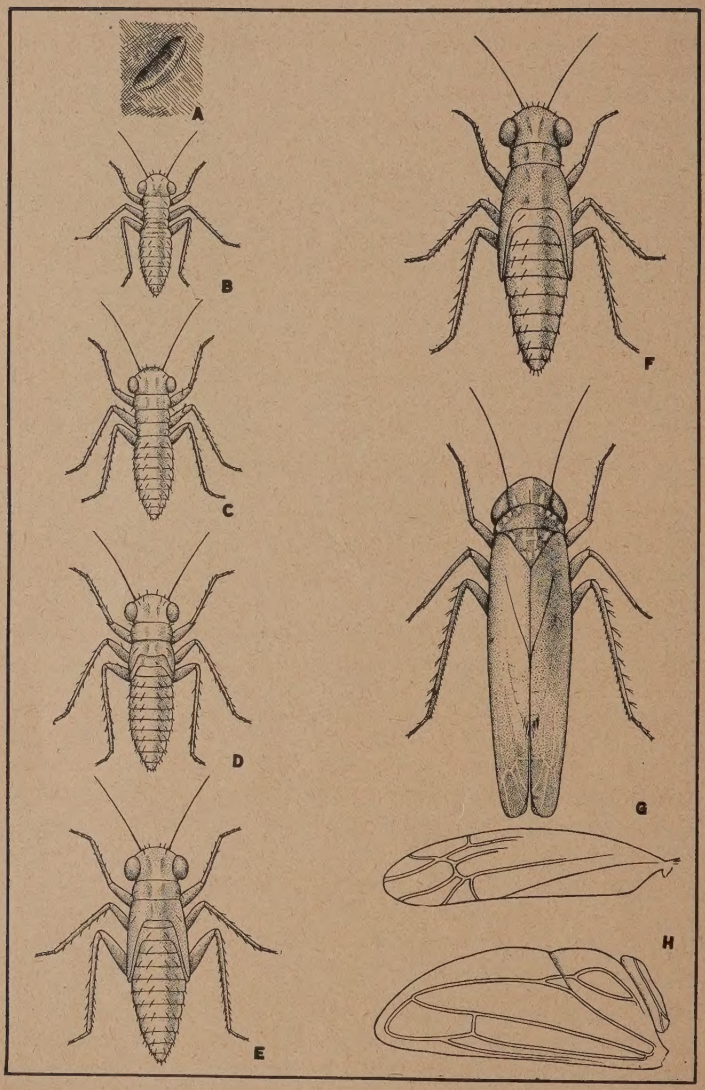

FIG. 2.—THE POTATO LEAFHOPPER

A. Egg in leaf tissue; B. first nymphal stage; C. second stage; D. third stage; E. fourth stage; F. fifth stage; G. adult stage; H. outer (elytron) and inner wing, showing venation.

the females have a long egg-laying period and it is possible to find nymphs in all stages from the last of June until well after frost in the fall.

How the Potato Leafhoppers Feed

Adults and nymphs of the potato leafhopper, like other leafhoppers, suck the juices or sap of plants through their delicate beaks which they insert through the epidermis of the leaf. In contrast to certain other leafhoppers, however, the potato leafhopper appears to feed only on the larger veins in the upper half of the leaf and not on the small veinlets. This affects the supply of sap while it is being distributed to the leaves so that the entire portion of the leaf supplied by the vein attacked is indirectly affected.

Plants Injured by Loss of Juices

The amount of plant juices lost through the feeding of any of the different kinds of leafhoppers is dependent upon the size and abundance of the insects. The injury which follows normally appears either as a yellowing or curling of the leaf which is sometimes sufficient to kill individual leaves but seldom the entire plant.

Potato Leafhopper Causes Distinct Injury

Close observations on injured plants have shown that the potato leafhopper is the cause of a distinct injury which follows its feeding on potatoes and several other plants. This distinct injury is called *hopperburn*[3] and begins with a slight yellowing, usually at the tip of a leaf. Later, as the injury progresses, the leaf turns brown, curls upward and withers. (Fig. 3.) The disease spreads from the tip or margin toward the midrib of the leaf, but spreads more slowly towards the base. The basal area of some leaves may remain green until the whole plant is nearly dead.

During periods of hot, dry weather, hopperburn spreads rapidly and whole fields of early potatoes may be killed in a week. (Fig. 4.) On the other hand, during cool, moist weather, or where protective sprays have been applied, hopper-

[3]Ball, E. D. The Potato Leafhopper and the Hopperburn That It Causes. Wis. State Dept. of Agri. Bul. 20, pp. 78-89, 1918.

FIG. 3.—HOPPERBURN ON POTATO LEAF

Photograph from upper surface showing typical brown, upcurled tip and margin. (Enlarged 4 times.)

burn is checked and throughout the summer shows nothing more than the primary symptoms.

Although hopperburn is communicated to the plant when the leafhopper feeds, it may also follow when the female inserts her eggs in the midrib or stem of the leaf. During the growing season of the potato, the injury always appears first on the lower leaves and gradually spreads to the upper ones. This is explained by the fact that nymphs tend to remain in the vicinity where they hatched until the adult stage is reached. New growth

is at first comparatively free of them but gradually becomes affected through feeding of the ever moving adults.

Leafhopper Proved to be Responsible for Hopperburn

In order to prove conclusively that the potato leafhopper is responsible for the transmission of hopperburn to potato and other plants, tests were made in the insectary with individual screened plants in pots and in the field with plants covered with large cages.

Tests with potatoes—In two tests in which a single adult "hopper" was placed on each plant, marked symptoms of hopperburn appeared in five days and progressed until in 16 days both plants were dead while two plants kept free of "hoppers" remained healthy throughout the test.

FIG. 4.—POTATO PLANT HALF DEAD FROM HOPPERBURN

During hot, dry weather whole fields may succumb to this injury in a short time.

In other tests where a number of adults were placed on potato plants, hopperburn appeared in from 10 to 21 days.

FIG. 5.—TWO APPLE SEEDLINGS SHOW EFFECT OF PRESENCE AND ABSENCE OF LEAFHOPPER.

Tests with beans—Two leafhoppers were placed on each of four potted bean vines. In less than two weeks all the vines became severely injured and three died. Vines kept free of "hoppers" remained healthy throughout the test.

Tests with apple—Two apple seedlings were growing in a flower pot. Four nymphs were confined in a cage on one seedling which in ten days became badly injured, while the other seedling free from "hoppers" remained healthy throughout the summer. (Fig. 5.)

In another test several small nymphs were placed on an apple seedling for some time but no injury appeared. Some weeks later two adults were placed on the same plant and following hopperburn injuries it died in two weeks. Adults taken from the field and placed on other seedlings produced the disease in from 10 to 21 days.

Tests with dahlia—Twenty newly-hatched nymphs were placed on a large, healthy dahlia plant. In seven days the plant was diseased and in 20 days was dead. A potted plant kept free of "hoppers" did not show injury and was still healthy at the end of 20 days. (Fig. 6.)

Although the typical injury did not appear in every test where leafhoppers were placed on food plants in pots—especially where nymphs were used—yet in a large majority of tests well developed symptoms of hopperburn were noted. It is certain then that even one or two leafhoppers are able to cause injury to a plant often to the extent of killing it. Males as well as females were found to cause the injury.

FIG. 6.—DAHLIA PLANTS READILY AFFECTED BY HOPPERBURN

The two plants were of equal size when the test started. The one on the left contained leafhoppers; the one on the right was protected from them by a large cage.

Field Tests

In order to carry out similar tests under field conditions, the following experiment was conducted: On June 12, 1920, when potatoes were breaking through the ground, large cages covered with fine mesh wire were placed over two hills of each of the following varieties: Early Triumph, Early Ohio, Irish Cobbler, Green Mountain and Rural New Yorker. These plants, protected by cages (Fig. 7) grew faster than plants in the rest of the field until, by the latter part of July, they were twice the size of unprotected plants. By the middle of August, however, the uncovered plants overtook the caged ones.

On July 12 fifteen adult leafhoppers were placed in one of the two cages over each variety. In each cage they reproduced so that in a short time there was an abundance of nymphs.

In the Triumph cage hopperburn appeared on July 21, or nine days after the "hoppers" were introduced. The disease spread steadily and in 23 days the plants were dead. The plants not subjected to leafhopper attack remained entirely healthy up to September 2 when they were dug. (Fig. 8.)

In the Early Ohio cage, hopperburn developed in two weeks after the "hoppers" were introduced, the plants dying late in August. Protected plants remained healthy all season.

Hopperburn appeared in the Irish Cobbler cage two weeks after the "hoppers" were introduced. By the first of September the plants were badly diseased and nearly dead, while the protected plants were fairly healthy.

In the Green Mountain cage hopperburn did not appear until July 29, or 17 days after "hoppers" began to attack the foliage. By September 9 the plants were affected with "burn" to a moderate degree. Plants protected in another cage had no hopperburn.

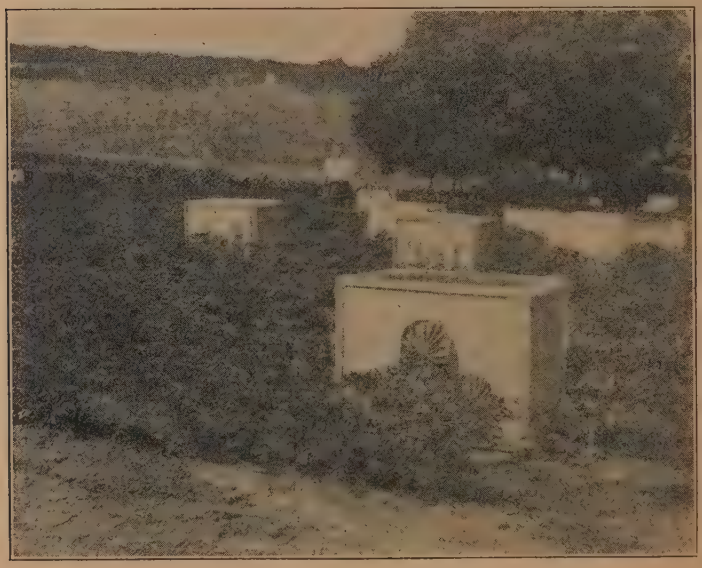

FIG. 7.—CAGES USED IN HOPPERBURN TESTS

In these tight cages some plants were protected from hopper attack all season. Hoppers were placed in other cages and produced hopperburn.

Plants on August 14 after hoppers were introduced
Same plants on September 2
Plants on August 14 kept free of hoppers
Same plants on September 2

FIG. 8.—ABSENCE OF HOPPER MEANS NO HOPPERBURN

Triumph potatoes caged for entire season. Leafhoppers introduced into one cage and kept out of other. 1920 experiment.

Hopperburn did not appear on Rural New Yorker foliage until August 3, or 22 days after introducing the 15 "hoppers" although there had been adults and numerous nymphs present right along. After starting, however, the disease progressed rapidly, and the plants were dead the first of September. The protected plants were perfectly healthy at this time.

Incidental observations regarding hopperburn were valuable. Numerous potato flea beetles and potato aphides were found in all cages, both those containing leafhoppers and those kept free of them. As the disease did not occur in cages protected from

the "hopper," it is quite indicative that these two insects do not transmit hopperburn.

Relation of Leafhopper to Hopperburn in the Field

During visits to potato growing sections of the state, it was observed that without exception, when the injury was found the potato leafhopper was always present, and no injury was present when leafhoppers were not found. The extent of hopperburn as affecting both individual plants and whole fields, was in close proportion to the number of leafhoppers present.

Several examples may be given: A field of Green Mountain potatoes on new land surrounded by woods was visited in August. It had not been sprayed. At first glance, the field appeared uninfested by insects. However, upon closer examination a leaf here and there was found which showed symptoms of the injury. Without exception, a leafhopper or cast skin could be found on or near every leaf thus affected.

In a field of Early Triumphs a fourth of a mile away, the amount of hopperburn was found to be much greater than in the field of Green Mountains. Likewise, the number of leafhoppers was much larger.

In a field of late planted Rural New Yorker potatoes neither leafhoppers nor hopperburn injury was found. An adjacent field of early potatoes was heavily infested and badly injured.

Hopperburn More Severe on Certain Varieties

Different varieties of potatoes are attacked to a different degree by the potato leafhopper, and different varieties are affected to a different degree by hopperburn.

The extent to which the same varieties are affected has appeared to be much the same at widely separated points in the state. The Early Triumph variety is always affected worst, the Rural New Yorker variety always least, and, moreover, the Rurals are always attacked most lightly by the leafhopper. The relative number of leafhoppers on other varieties varies considerably.

It is believed that the leafhopper has a preference for certain varieties of potatoes of tender foliage and that these same varieties

may be more susceptible to hopperburn than sturdier varieties with hardier foliage.

Some Plants Are Resistant to Hopperburn

Observations for two seasons indicate that certain plants of a given variety have greater resistance to the leafhopper and hopperburn than have adjacent plants of the same variety. During the summer of 1919 in an unsprayed plot of Rural New Yorker potatoes, three plants although continually infested, remained practically uninjured, while the surrounding plants without exception became badly affected. The same was true to a greater or less degree with other varieties.

In order to test the resistance to hopperburn of individual plants of each variety, seed potatoes were selected in 1919 from Early Ohio, Irish Cobbler, Green Mountain, Rural New Yorker and Late Puritan plants. Two kinds of tubers were chosen at digging time from 12 vines of each variety; those from the six largest and greenest vines most free from hopperburn, and those from six vines which had been the first to die from the effects of hopperburn. The size of the tubers was not regarded in this selection.

In 1920 a plot of ground was set aside for this experiment and one row planted to each variety of the selected tubers. The north half was given over to tubers from the healthy vines of the year before; the south half was planted to tubers from the diseased vines of the year before.

A row of Wisconsin certified Early Triumph seed was planted as a check. The plot was sprayed four times with bordeaux mixture, 4-4-50 combined with lead arsenate, 2½-50.

An area of six feet across the extreme north end and extreme south end was reserved as a check and not sprayed.

Rurals—During most of the summer the foliage of plants from seed of diseased vines was heavier and more abundant than foliage of plants from seed of healthy vines. By the last of August there was little difference. The infestation of leafhopper adults and nymphs was slightly greater on plants from seed of diseased vines throughout most of the season. These plants became affected with hopperburn about the middle of July. It spread slowly the remainder of the season until at

digging time it was rather severe. Practically no "burn" occurred on the plants from seed of healthy vines until the latter part of August.

The amount of foliage and infestation on the two kinds of check plants was much the same as with the treated plants. The hopperburn, however, was much more severe on the plants from seed of diseased vines than on the others.

Green Mountains—Plants from seed of diseased vines had more foliage than plants from seed of healthy ones until the middle of August when conditions were reversed. The infestation of adults and nymphs also was greater on plants from seed of diseased vines until mid-August when it became greater on the others. Hopperburn occurred on both kinds of plants and increased gradually during the season. It was always more severe on plants from seed of diseased vines, especially during the latter part of August.

The amount of foliage and infestation on the two kinds of check plants was much the same as on the corresponding treated ones. Hopperburn, however, was much more severe on plants from seed of diseased vines.

Early Ohios—As with the two former varieties, plants from seed of diseased vines had more foliage than plants from seed of healthy ones up to the middle of August when they were practically dead. Plants from seed of healthy vines although severely affected with hopperburn lived two weeks longer. The infestation of adults and nymphs was a little greater on plants from seed of diseased vines. Hopperburn occurred on both kinds of plants in nearly equal severity up to August 10. From then on it was far worse on plants from seed of diseased vines.

Conditions of leafhopper infestation and foliage on the two kinds of check plants corresponded closely to conditions on the treated ones. "Burn," however, was more severe on check plants from seed of diseased vines.

Irish Cobblers—The foliage of plants from seed of healthy vines was more abundant from the first than the foliage of plants from seed of diseased vines and lived two weeks longer. The infestation of adults and nymphs was generally much heavier on plants from seed of healthy vines in contrast to any other variety. Hopperburn, although prevalent all season on both kinds

of plants, was much more severe on plants from seed of diseased vines.

More nymphs occurred generally on check plants from seed of diseased vines, and hopperburn was much worse on them than on check plants from seed of healthy vines.

Late Puritans—Foliage of plants from seed of healthy vines was much more abundant throughout the season than that of plants from seed of diseased vines. There was practically no difference in infestation of leafhoppers between the two kinds of plants. No hopperburn occurred on plants from seed of healthy vines until mid-August and it never became severe. On the other plants it appeared late in July and became severe by September.

There were always more nymphs on check plants from seed of diseased vines than on the others. "Burn" also was more severe on them and increased rapidly until in September it was very heavy. At this time "burn" was moderate, on check plants from seed of healthy vines.

The check plants of all varieties showed far greater difference in individual resistance to hopperburn than did those which were sprayed. The check plants coming from seed of the healthiest vines the year before held up much better under leafhopper attack and hopperburn, than did check plants from seed of diseased vines of the year before.

Although this experiment shows that certain plants have considerable more resistance to hopperburn than others of the same variety, a warning should be given. It is just as important to select according to the size and abundance of seed as to consider the health of the vines. It was found at digging time that many of the plants most resistant to hopperburn produced many small, inferior tubers.

Conclusions—For four out of five varieties, leafhoppers were found in greatest numbers on the plants which had the most abundant foliage during all or part of the summer. On the other hand, hopperburn without exception was worse on plants from seed of diseased vines whether or not they had the most abundant foliage. This was especially noticeable in the checks. It promises to be of interest to find the relation of plants seemingly preferred by the leafhopper and plants seemingly resistant to disease to their relative yield.

Soil Moisture May Affect Hopperburn

Hopperburn appears and spreads quite rapidly during hot, dry weather; and there are indications that the soil moisture available for potato plants exerts much influence upon the amount of "burn" likely to occur. With an equal abundance of leafhoppers it is believed that hopperburn would be far less serious in years when there is ample rainfall during the growing season than in dry seasons.

Potato Leafhopper Visits Many Plants

A large number of plants are visited by this leafhopper. In the order of greatest injury from hopperburn they are: Potato, bean (pole, string, navy, lima), hemp, beet (sugar, table), apple, raspberry, red clover, Swiss chard, strawberry, soybean, cucumber, rhubarb, lettuce and the hop tree. Among flowers and trees the following are visited: Dahlia, hollyhock, syringa, weigelia, sumac, dandelion, elm, box-elder, burdock, Indian currant and rose.

Although many of the above plants are used merely for feeding or even resting, reproduction is known to occur on potato, beans, hemp, apple, dahlia, and box-elder. Potato, without a doubt, is the favored host for reproduction with bean a close second. Hemp, sugar beet and apple (nursery stock or water sprouts) are more heavily infested with "hoppers" when growing near patches of potatoes or beans. Under such conditions reproduction takes place readily on them.

It was formerly known that hopperburn occurred on potato, beans, apple, raspberry, box-elder and dahlia. Additional plants recently found affected are beans (all varieties mentioned above), sugar beets, hemp and hollyhock.

Beans Severely Affected by Hopperburn

String and pole beans are as readily attacked by the potato leafhopper and as severely affected with hopperburn as are potatoes. Navy and lima beans are rather free from leafhopper attack and hopperburn. String beans in many parts of the state have been severely injured and the yield greatly reduced. A large field of pole beans heavily infested by the insect became diseased to such an extent that no pickings were made. Sprays had not been applied.

Observations were made on a large patch of beans of four varieties: Navy, string, bush lima and pole. Four applications of bordeaux mixture combined with lead arsenate were made

FIG. 9.—LEAF OF SUGAR BEET AFFECTED WITH HOPPERBURN
Brown, curled-up tip and margin of smaller leaf shown by arrow.

during the season. Pole beans were most heavily attacked by the "hopper" and suffered most from "burn" just when the pods should have been developing. String beans suffered next to the pole variety although a good crop of pods developed. Navy beans were not affected severely by hopperburn. Bush limas were practically uninjured. Very few adults or nymphs could be found on them at any time and no "burn" appeared until late in the season. A nearby field of soybeans was watched for comparison with the other varieties. No sprays were applied. The infestation of adults and nymphs was light at the beginning of summer and increased slowly until September. It never became heavy. Hopperburn was at all times light.

Sugar Beets May Suffer

The potato leafhopper will attack sugar beets in the early summer and reproduce thereon to some extent, but until nearby potatoes are dead the infestation is not heavy nor is hopperburn severe. A large field of sugar beets 200 yards distant from potatoes was found early in July to be lightly infested with adults and nymphs. Typical symptoms of hopperburn were evident. (Fig. 9.) This field remained lightly infested the rest of the summer and "burn" never became severe.

Another field observed joined a large patch of early potatoes just about dead from hopperburn. Leafhoppers were migrating in vast numbers from the potatoes to the beets. The first few rows of beets (next the potatoes) were very heavily infested with leafhoppers in all stages. Farther in, their numbers became steadily less until near the other side of the field the "hoppers" were few in number and well scattered. Hopperburn although not severe at this time was much heavier in the rows adjoining the potatoes than in the rows on the other side.

Natural Enemies Not Important in Control

Three enemies known to attack the potato leafhopper were observed during the season 1919. One, a tiny, wasp-like parasite, breeds in the leafhopper eggs. This parasite is general in southern Wisconsin, but does not occur in sufficient numbers to materially reduce the number of "hoppers."

Another enemy, a fungus disease, attacks both adults and nymphs. It was common all over the state in 1919, but apparently killed the greatest number of leafhoppers in the northern potato-growing sections. Warm, moist weather appears to be necessary for the rapid spread of the fungus. Leafhoppers affected with the disease soon die and turn from green to yellowish in color. In a short time a heavy fungus growth appears on the insect's body. (Fig. 10.) The fungus grows until the body is entirely enveloped in it and a striking blue and green irridescence appears, making the disease easy to recognize.

Spiders frequently catch and kill young nymphs or even adult leafhoppers.

Neither the parasite nor the fungus disease was found during the season of 1920. Although the parasite was no doubt present

in small numbers, no specimens were secured. The fungus disease was looked for in several potato sections of the state but weather conditions were not right for its best growth.

Bordeaux Controls Leafhopper and Prevents Hopperburn

Proper application of the spray is perhaps the most important feature in controlling the potato leafhopper. It *must* be applied

FIG. 10—ADULT POTATO LEAFHOPPER KILLED BY A FUNGUS.
During warm, moist weather this fungus may spread rapidly and greatly reduce the number of hoppers. (Enlarged 11 times.)

to the under side of the leaves and may well be applied *also* to the upper surface. The spraying must be thoroughly done, covering practically all of the foliage on the under side.

A high pressure (150 pounds, at least) should be maintained in order to cover the leaves with a fine mist, rather than with a coarse spray. Even with a hand-spraying outfit (Fig. 11) at least two adjustable angled nozzles on adjustable arms or booms (Fig. 12) should be used. Both sides of every row of plants can then be sprayed. If larger machines are employed, more rows may be sprayed at one time. A pressure gauge should be used on all pressure sprayers so that the operator may know whether or not the pressure is up to 150 pounds.

Spray Early—At least three applications should be made.[4] The first spray should be applied about the middle of June or when leafhoppers appear in numbers. It is often possible to time

FIG. 11.—AN EFFECTIVE TYPE OF WHEELBARROW SPRAYER FOR SMALL PATCHES

This sprayer has a capacity of 12 gallons. A pressure of 150 pounds can be kept by using two nozzles. Spray can be seen coming from the nozzles on the right.

this spraying so that with an arsenical added, the Colorado potato beetle also may be controlled.

The second spray should be applied in from ten days to two weeks from the first. The potato plants are growing rapidly at this time and offer new foliage to leafhopper attack. Frequent rains may be expected which wash off much of the material. Therefore, the second application should be timed accordingly.

The third spray should be applied about two weeks after the second, depending upon the following conditions: If new growth is infested by leafhoppers; if there is an abundance of leafhoppers in field; if the weather is hot and dry. (Hot, dry weather is very favorable to rapid spread of the injury.)

A fourth spray might well be given to advantage from the first to tenth of August when some of these conditions exist: A hot dry summer; heavy, new growth in late summer, or great abundance of leafhoppers in field.

[4]It is preferred not to give exact dates, because the time of spraying is bound to vary in different parts of the state.

Experiments Show Value of Sprays—Four plots were used for treatments in 1919 and three in 1920. It was thought necessary to have the plots widely separated in order that the treatment for one should not in any way affect another, especially as swarms of leafhoppers might be driven by the spray from one plot to another. In having the plots at considerable distances

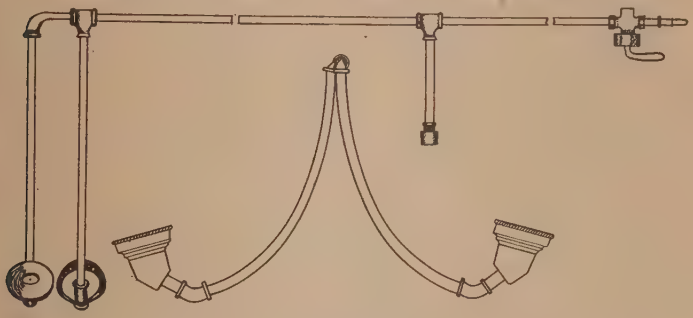

FIG. 12.—ADJUSTABLE SPRAY BOOM USED IN LEAFHOPPER EXPERIMENTS.

The boom may be adjusted in three ways: first, by bringing the arms together or spreading them apart which simply loosens or tightens the threads of the coupling; second, by turning the 45" couplings just below the nozzles; and third by turning the angled nozzles themselves.

from each other, it was not possible to secure uniform growing conditions as to slope, fertilizer or character of soil. The best spray used therefore will be indicated principally by the amount of feeding injury and disease present on the foliage during the summer and not alone by relative yields.

EXPERIMENTS IN 1919

Bordeaux Mixture Proves Most Practical

One plot of Rural New Yorker and Green Mountain potatoes was sprayed four times with bordeaux mixture, using 4 pounds copper sulphate and 4 pounds unslacked lime to 50 gallons of water.

There was a moderate infestation of adults and nymphs in this plot when the first spray was applied but it gradually decreased up to the middle of July. From then to the end of the summer, there was a remarkable scarcity of both adults and nymphs especially on the Rurals. Newly-hatched nymphs appeared every day but disappeared in a short time.[5] Untreated

[5]Fluke, C. L., Jr.—Does Bordeaux Mixture Repel the Potato Leafhopper? Jour. Econ. Ent. Vol. 12, No. 3, pp. 256, 257—1919.

rows of each variety between the treated rows were heavily infested with the adults and nymphs throughout the summer.

Hopperburn appeared on tips of leaves scattered all over the plot after the second spraying and before nymphs began to hatch. On the Rurals it remained without spreading to any extent up to harvest. On the Green Mountains it spread very slowly and at digging time had not become serious—that is, probably not more than one-fourth of any plant had dead leaves. (Fig. 13.)

On the untreated rows the injury spread without interruption from the tip along the margin and to mid-rib and finally to the entire plant. At digging time, Rurals showed some injury on every leaf; Green Mountains were badly affected and many plants were dead.

FIG. 13.—TYPICAL CONDITION ON SEPTEMBER 5 OF PLOTS TREATED WITH BORDEAUX MIXTURE

The vines were heavy and in fair condition. The yield was greater than that from untreated plots. 1919 experiments.

Bordeaux Mixture and Nicotine Sulphate Give Effective Control

Two adjacent plots of equal size were planted to six varieties of potatoes—Early Triumph, Early Ohio, Irish Cobbler, Green

FIG. 14.—PLOT SPRAYED WITH BORDEAUX-NICOTINE REMAINS HEALTHY AND YIELDS HIGH

On August 23 the six varieties of potatoes were in good condition. Compare with Fig. 15. 1919 experiments.

Mountain, Late Puritan and Rural New Yorker. One plot was given maximum protection by being sprayed five times with bordeaux mixture, combined with nicotine sulphate for the last two treatments (6 fluid ounces to 50 gallons of bordeaux). The other plot received no protection from the leafhopper. A very heavy infestation of "hoppers" and frequent rains seemed at the time to require the five sprayings if maximum protection was to be given. It is probable that four applications would have been sufficient.

When the first spray was applied, leafhopper adults and nymphs were present in the treated plot in from moderate to large numbers. By the middle of July, however, a great decrease in their numbers was noticed. A week later, practically no nymphs and only an occasional adult could be found on the sprayed plot. This condition continued up to digging time.

The unsprayed plot was at all times rather heavily infested with both adults and nymphs and the numbers increased as the season advanced.

The treated plot immediately adjacent to a continual source of leafhoppers remained in excellent condition throughout the summer, the Early Triumphs being the one exception.[6]

A slight amount of hopperburn appeared on the tips of scattered leaves in the plot early in the season, but did not spread noticeably all summer, even during a period of hot, dry weather.

FIG. 15.—PLOT NOT TREATED IS BADLY DISEASED ON AUGUST 23
This plot next to the treated plot shown in Fig. 14 is seriously affected with hopperburn. Early varieties in the center are dead. 1919 experiments.

On Late Puritans and Rurals there was almost no injury. On the remaining varieties it was generally light. (Fig. 14.)

The untreated plot showed first signs of the injury early. In contrast to the treated plot the injury spread rapidly until midsummer, at which time the early varieties were practically dead and the late badly affected. (Figs. 15 and 16). The Rurals showed less injury at digging time than any other variety.

Thus the plot given maximum protection showed a considerable beneficial contrast to the plot given no protection.

Nicotine Sulphate Alone Does not Control Hopperburn

One plot of Early Ohio and Rural New Yorker potatoes was sprayed four times with nicotine sulphate and fish oil soap (using 6 fluid ounces of nicotine and 2 pounds of soap to 50

[6]The Early Triumph seed came from vines which had been killed the previous year by hopperburn. Both sprayed and unsprayed vines became seriously affected with hopperburn early in the season and were dead by the middle of July.

gallons of water.) Four applications were necessary because of the enormous number of leafhoppers present and the hot, dry weather. The treatments did not noticeably reduce the infestation of adult hoppers so that the eggs were laid right along and young nymphs appeared without cessation. Nymphs present when the spray was applied were readily killed, but no repellent effect

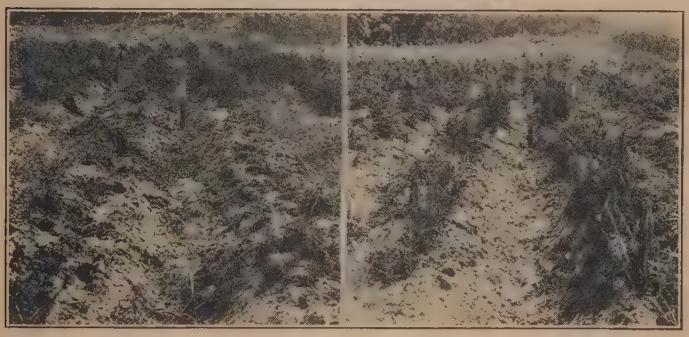

FIG. 16.—TYPICAL CONDITION ON SEPTEMBER 5 OF UNTREATED PLOTS

As shown by rows in the foreground, untreated plants were entirely dead at digging time. 1919 experiments.

was observed. (It should be remembered that the effect of nicotine sulphate sprayed on plants is not lasting.)

Hopperburn appeared in this plot a few days after the first spraying. On the Early Ohios, it spread slowly and surely, until the first week in August when all plants were practically dead. The treated rows were in as bad condition as an unsprayed row.

The Rural New Yorkers, although as heavily infested all summer as the other potatoes, remained fairly free of injury. By the middle of August, however, hopperburn began to spread to these plants and in a week about half of each plant was dead. An untreated row was slightly more affected than the others.

Kerosene Emulsion Does Not Control Hopperburn

One plot of Early Ohio and Green Mountain potatoes was sprayed three times with kerosene emulsion diluted to contain 10 per cent kerosene.

The infestation of adults was not noticeably reduced. Nymphs present at the time of spraying were readily killed, but great num-

bers continued to hatch and did not appear to be killed by any oil remaining on the leaves. There was no repellent effect observed upon adults or nymphs. The Early Ohios were practically dead by the last week in July. The Green Mountains were badly affected by the middle of August. The untreated rows of each variety were in slightly better condition than the treated rows.

Yields

The yields of the four treated plots and the untreated rows are summarized below. The exact yields per acre are not given on account of the difficulty in figuring acre yields from such small plots. The proportionate yields of treated and untreated rows, clearly shows that protective sprays have a decided value.

Bordeaux mixture plot—The treated rows of Rurals yielded twice as many potatoes as the untreated rows; the Green Mountains yielded practically twice as many in the treated rows. The ground in this plot was lacking in fertilizer.

Bordeaux-nicotine plot—The two rows of each variety in the treated plot yielded in proportion to the two rows in the untreated plot as follows:

Early Triumph—no marketable potatoes in either plot.

Early Ohio—twice as many as in the check.

Irish Cobbler—two and three-fourth times as many as in the check.

Green Mountain—two and one-third times as many as in the check.

Late Puritan—two and one-sixth times as many as in the check.

Rural New Yorker—one and fourth-fifth times as many as in the check.

The ground comprising these two adjacent plots had been well manured and was in good condition.

Nicotine sulphate plot—The treated rows of Early Ohio potatoes yielded one and one-half times as many tubers as the untreated rows; the treated rows of Rurals twice as many as the untreated rows. This plot has been manured from time to time.

Kerosene emulsion plot—The treated rows yielded one and one-fourth times as many Early Ohio potatoes as the untreated rows, and one and one-fourth times as many Green Mountains as

the untreated rows. The ground comprising this plot had not been fertilized for some time.

Conclusions—The treated rows gave much higher yields, ranging from one-fourth higher with Early Ohios and Green Mountains sprayed with kerosene emulsion, to two and three-fourth times as high with Irish Cobblers sprayed with bordeaux-nicotine.

Rural New Yorkers showed less difference in yield from three kinds of treatment than any other variety. They also were infested less by the leafhopper than any other kind. That it paid to spray them, however, is clear.

EXPERIMENTS IN 1920

Bordeaux Mixture Again Proves Effective

Bordeaux mixture, the most practical spray used in 1919, was given a severe trial in 1920 on a large plot of ground planted to five varieties of potatoes; Early Triumph, Early Ohio, Irish Cobbler, Green Mountain and Rural New Yorker. We wanted to see if this spray would again have the effectiveness in controlling the potato leafhopper and thereby largely preventing the appearance and spread of hopperburn. The plot was sprayed four times with bordeaux mixture. A good portion of each variety was left unsprayed as a check.

Early Triumph[7]—The infestation of adults and nymphs was generally light to moderate, at no time being heavy, although relatively more "hoppers" could be found here than on any other variety. On the check a heavy infestation occurred most of the summer. Hopperburn appeared the last of June, but due to the beneficial effect of bordeaux spread slowly although steadily until the vines died the last of August. The unsprayed vines were severely affected with the disease, dying early in August. (Fig. 17.)

Early Ohio and Irish Cobbler—The infestation of adults and nymphs on these two varieties was generally light all summer. During the latter part of the season it was often difficult to find any "hoppers" at all. The check plants were moderately infested early in July and became very heavily infested early in

[7]This variety was certified Wisconsin seed and did not die of hopperburn nearly as soon as did the plants from diseased vines used in 1919.

FIG. 17.—TRIUMPHS WITHSTAND LEAFHOPPER ATTACK WHEN SPRAYED WITH BORDEAUX.

Plants at right of stake sprayed four times and still green; plants at left of stake not sprayed and dead. 1920 experiments.

August. Hopperburn appeared on both varieties early in the season but was held in check by bordeaux up to August. From then on it spread gradually and by September was rather heavy. The vines were unhealthy looking but not dead. "Burn" on the check plants was heavy by the last of July and all vines of both varieties were practically dead by the middle of August.

Green Mountain and Rural New Yorker—Few leafhoppers, either adults or nymphs, were found all season on these varieties. Many were found on the check plants, the infestation becoming heavy before the end of the season. Hopperburn was not severe on the Green Mountains and on September 14 the vines were green and fairly healthy. Little disease occurred on the Rurals, the vines remaining green and healthy up to the middle of Sep-

tember. The beneficial effect of bordeaux was very noticeable. On the check plants, however, hopperburn was severe especially during August. The Green Mountain vines were dead early in September. The Rurals were severely affected but not dead.

It was repeatedly observed on all the varieties that the infestation of leafhoppers decreased greatly after an application of bordeaux and a week or two elapsed before an increase was again noticed.

The yield of the five varieties was small on account of a dry season and because they were planted on a light, sandy slope, but the treated portion of the plot yielded more tubers for each variety than did the untreated portion.

Recommendations for Control

Spraying appears to be the only practical method of controlling the potato leafhopper and thus preventing the appearance or spread of hopperburn.

Bordeaux mixture, 4-4-50 is effective in repelling the insect and in checking the "burn." This spray alone should suffice.

Spray the *underside* of the leaves thoroughly. Use a good sprayer in first class condition and keep the pressure up to at least 150 pounds. Use nozzles throwing a fine mist. Spray each side of each row. Spray three times at least. If you have sprayed three times, spray once more if leafhoppers or hopperburn persist.

Great difference in the severity of hopperburn on different varieties of potatoes has been shown by the foregoing experiments. Of the varieties used, Early Triumphs were always affected worst; Rural New Yorkers always least. Therefore, Triumph potatoes should be sprayed early, often, and with great care in order to preserve the foliage until a crop of tubers has had time to develop. Early potatoes generally should be more closely watched than late ones. Rurals could better withstand a delay in spraying or lack of an extra spraying than any other variety used in these experiments.

Use More Bordeaux

It has been used with success for many years in the control of early and late blight and of the potato flea beetle.

It is an effective control of potato leafhopper and hopperburn.

An arsenical added to bordeaux mixture makes a spray which will assure a crop in spite of nearly all insects and diseases which attack the foliage.

It is a universal and vital treatment for potatoes, and should be applied often, properly, and thoroughly.